THE RENEWAL AND TRANSFORMATION OF HIGH, MEDIUM AND LOW TECH: A COMPARATIVE APPROACH

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Abstract

In the past decade, innovation studies have mainly focused on the High Tech (HT) sector due to its soaring Return on Investment (ROI), and the critical role it plays building societies and new economies. As a result, the innovation literature focus has deviated from the traditional, Low and Medium Tech (LMT) to HT sectors. This study, among a series of recently published work, stresses the major importance of LMT sectors in our current economies. Literature suggests that LMT sector is witnessing major multidimensional transformation, responding to changes in local and global markets. This research work compares LMT to HT sectors from an innovation perspective. It addresses multiple factors such as the nature of customers and their needs, the knowledge production mechanisms, the various factors that influence innovation in the firm's own sector, the resources inflow, growth in the sector, and the strategic and competitive dynamics dimension. Our results suggest a renewal and transformation is occurring to both the LMT and HT sectors. LMT is shifting towards differentiation, while HT is increasing its cost awareness dimension. Furthermore, HT firms are using both the linear model of innovation as well as the open innovation model. Firms in LMT that are generally conceived to be supplier dependent are enhancing their internal knowledge production mechanism to support their differentiation strategy. This renewal process did not misbalance the supplier, user role that HT and LMT play respectively. In fact our results show that LMT is still the user of the General purpose technologies that HT produces.

Keywords - *Pavitt taxonomy, Product innovation, Process innovation, Knowledge production, Open innovation, Linear model of innovation*

Introduction

After the Second World War, the US government lent special attention to various strategic industries. The most important of which were: defence, safety and health (Bruland & Mowery, 2005). This focus materialized by increasing governmental spending to foster Research and Development (R&D) in the targeted sectors. As a government intervention policy, R&D industrial funding became more rooted in the development of the various target industries. This laid the definition of the 'Linear Model' of innovation; a model that relies in its core premises on boosting internal R&D to invent new technologies. Consequent to this Schumpeterian (Mark II) movement, the HT sector evolved rapidly to include large incumbent firms. Those firms were R&D centric, and basically created demand through their radical innovations. Pushing technologies and educating the customer base, were the main ingredient of those large firm's core strategic directive. This Mark II era, typically from 1945 to 1980, was characterized by weak formal protection. Not a surprising assertion indeed, since most of the firms at that time depended on secrecy, due to the linear model of innovation they generally adopted.

In the early 1980s, as a prime reaction to the weak form of protection and the increasing role of venture capitalism, new firm entries increased dramatically. Small Medium Enterprises (SMEs), that were often seen as non-threatening started a wave of creative destruction. This wave led to what is coined 'The third industrial revolution' (Fagerberg, 2005). Radical products that primarily depended on specialized knowledge, created a new breed of firms. Firms that were knowledge driven managed to threaten the existence of large well established, incumbent firms. This turbulent, extremely dynamic environment is a key characteristic of new, HT industries compared to LMT mature industries. This somehow independent rise of the HT sector, created a sector that has distinguished, unique characteristics if compared to the classical LMT sector. At the beginning of its rise, the HT sector was subcontracted to serve major governmental projects. Later, due to the convergence of technologies and the rise of standards, the applicability of HT products became wide, and covered all non-governmental contracts and sectors. As a result, bidirectional dependability emerged between HT and LMT, where the former became the supplier of the later. To put it simply, the HT sector took the role of the main supplier, and the LMT sector the user's role.

LMT is classically regarded a lagging sector in terms of growth, innovation and various other economic indicators. Recent studies, however, demonstrated that LMT is currently witnessing a major renewal and strategic shift. In the year 2000, the OECD (2003) reported that the Low Technology (LT) sector alone, contributed to more than 32% of global manufacturing exports (Mendonca, 2009). Growth in LMT is highly noticeable. For instance, in 1969, the total production of machine tools represented 9M$ (Liu and Brookfield, 2000). In 2006, according to Gardner Publications (2007), this amount has reached 3.7B$ (Chen, 2009).

Our results suggest a renewal in LMT accompanied by further adjustments in HT firms' strategy both on the firm and external to the firm levels. The paper is organized as follows; Section 1 includes a short review of the pertinent literature the theoretical framework and the research hypotheses. Section 2 presents the survey data, the methodology used, the selection of variables, how they relate to the research hypothesis and the theoretical framework. After, the paper explores the primary results in Section 3, and is followed by a detailed discussion that includes the validation of hypotheses and implications from the results in Section 4. Section 5 concludes with future research work projected.

Theoretical Framework and Research Hypotheses

The theoretical framework of the paper will address various factors divided into two groups. The *first group* of factors is firm specific and the *second group* addresses external factors (with respect to the firm). The first group will include: the firm's strategy, absorptive capacity, technology and knowledge management processes. The second group will include the influence of customers, universities and government as external entities to the firm. Figure 1 shows the conceptual framework, based on which hypotheses are developed. The study will be carried out on the firm level and the two views (from within and without the firm) are presented. Figure-1 shows the interactions and dependencies between the different agents considered in the theoretical framework.

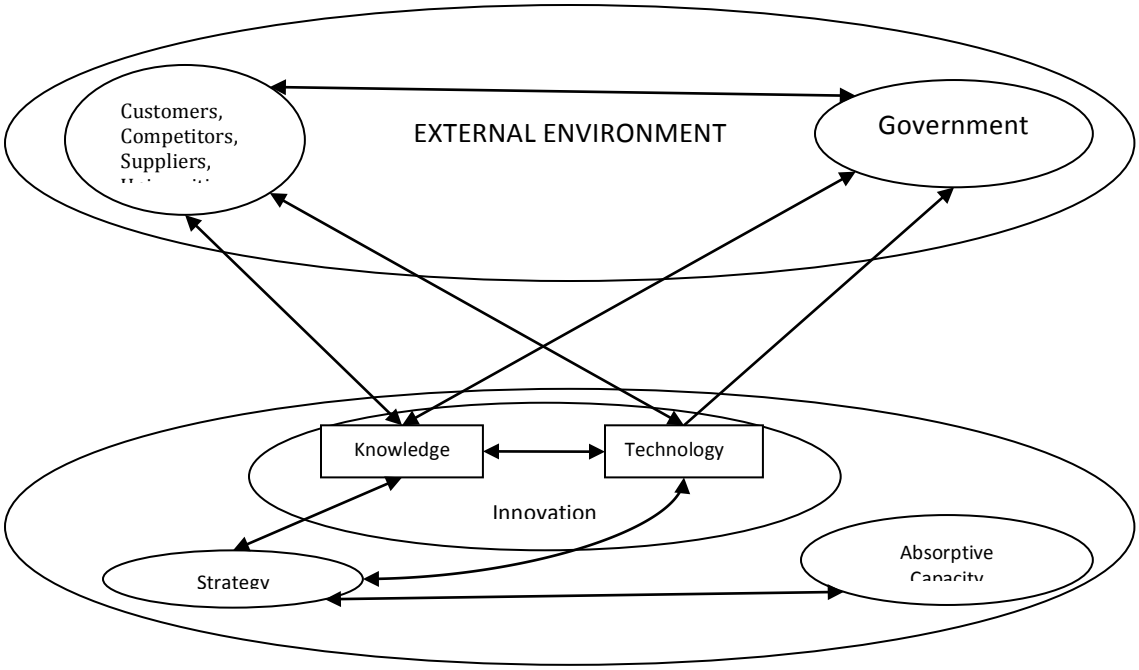

Figure 1 – Conceptual framework

Firm specific factors (from within)

Strategy

LMT firms are traditionally focused on cost based strategy. This mature sector has already developed its major breakthrough innovations and capitalized on them. Later, the sector was primarily focused on enhancing the manufacturing and services processes altogether. With severe price competition, firms fighting for survival in that sector have started to shift their strategies from cost driven strategies towards differentiation strategies (Robertson et al., 2009). Differentiation is carried out by putting more focus on product quality and enhancing the manufacturing process, while maintaining competitive prices. Classical examples include, the use of software programs to control manufacturing tools, and the use of database programs to manage inventory, in manufacturing facilities. As a result, firms in LMT created a demand to the HT sector to provide them with the necessary technologies. This is a phenomenon that created a sort of dependability between the two sectors, LMT as the user, and the HT serving as the supplier. This dependability was not evident in the early 80s when the third industrial revolution was still in its early beginnings. This strategic renewal on the firm's level is due to two main factors. The first is the maturity of certain technologies provided by HT that could be exploited by LMT firms. The second is the nature of those technologies that are generally fit for deployment in LMT. This category of technologies was labelled 'General Purpose Technology' (GPT). GPT is defined as a technology that helps change in a radical way, existing technologies (Freddi, 2009). GPT is classically the output and the maker of industrial revolutions. For instance, the steam engines, chemical radical innovations, ICT products are all considered GPT.

The HT is the product of the third industrial revolution, characterized by producing GPT (Fagerberg, 2005). The ICT for instance is constantly explored by LMT to enhance its information systems, and is an example of a GPT. It is important to note that General Purpose Technologies (GPT)s are technologies that have the ability to spill out of their home industries to other older industries (Von Tunzelmann and Acha, 2005). Consequently, technologies defined as GPTs "Often have the properties of being able to become pervasive, through their take-up in one industry after another" (Freeman and Perez, 1988; Freeman and Louca, 2001). Industries able to drive that kind of dynamism are therefore considered GPTs (Helpman, 1988). As a result, it can generally be considered that ICT is considered a GPT. This is evident from the innovation that ICT spills over from its own sector to other classical LMT sectors that are heavily dependent on their own products. ICT managed to diffuse in almost all sectors in our society that range across the various low and medium technologies like textile, chemicals, automobile manufacturing and so on. Those industries adopt the various ICT products (such as software, hardware, telecommunication equipment) in their manufacturing process.

HT firms are usually focused on differentiation and focus (Viardot, 2004). This is natural since those firms' main competitive advantage is to provide superior technologies, to serve other sectors (including the LMT). Consequently, unlike the LMT that is cost centred, HT firms focus on R&D investment, and protecting their innovative ideas. Differences in firm objectives across the two sectors, is definitely a key factor influencing the variability of strategy formulation and execution. This brings us to our first hypothesis relating to firm strategy:

H1: Firm Strategy: Firms in HT follow a combination of focus and differentiation strategy, while firms in LMT are cost focused. Firm in HT are product innovation focused, while in LMT firms are process oriented (Ghosal and Nair-Reichert, 2009; Santamaria et al., 2009; Heidenreich, 2009).

Absorptive capacity

The firms' ability to identify, activate and manage external sources of knowledge for success is what is generally referred to as the firm's absorptive capacity (Cohen & Levinthal, 1990). Increasing a firm's absorptive capacity increases its awareness of market and technological trends. This assists in predicting future development, engages into various forms of innovation through the combination of various accumulated knowledge. As a result, search strategies should align with a firm's own absorptive capacity. In LMT, a generally stable industry, innovation success is dependent on firms' absorptive capacity focused on the market input (from customers and competitors). In contrast, innovation success for HT firms is dependent on the absorptive capacity focused on deep technological knowledge and expertise (Grimpe & Sofka, 2009).

On the one hand, LMT firms enhance their absorptive capacity by hiring resources that support the firm's search strategy, focused on market input. Resources usually include personnel with generalist profiles, in the various financial and technological areas. For instance, on the technological side, when studying Taiwan's machine tool industry, Chen (2009) found that the industry depended heavily on trained engineers. Those engineers were the principal ingredients of their firm's absorptive capacity. Furthermore, they were key elements in the knowledge transfer process. On the other hand, HT firms, whose core competitive advantage is

technological superiority, are expected to be more focused on highly technical staff with deep technological knowledge in their field of expertise. This dependability is obvious when examining the market mobility trends, and the way HT firms attract highly trained, research oriented technical resources in their R&D departments. That in mind, we state our second hypothesis on absorptive capacity as:

H2: Firm Absorptive Capacity: In HT, firms are gradually accumulating knowledge from within, while firms in the LMT benefit more from external collaboration and interactions. Furthermore, firms HT search strategy should be better due to their more efficient absorptive capacity (Grimpe & Sofka, 2009).

Technology, Knowledge and R&D management

Technologies can be developed in house, or acquired. Let us first examine technology acquisition. Technology acquisition can take several forms: through the use of Mergers and Acquisitions (M&As), Licensing Contracts (Inward Technology Licensing-ITL), formal or informal cooperative modes of R&D together with collaborative networks agreements on technology activities (Tsai & Wang, 2009). ITL's main characteristics are: helping a firm to lower its cost and allocate extra focus on marketing its own technologies; facilitate technology acquisition, since the supplier might not be willing to sell the technology; decreased competitive advantage, since other firms could be using the same technology (Zahra et al., 2005). It was however found, by Tsai and Wang (2009) that ITL does not significantly contribute to a firm's performance in LMT. The main difficulty referred to by the authors is the integration between old and new technologies.

According to Tsai & Wang (2009), outsourcing and licensing technologies might penalize technological innovation. First, firms should clearly identify their core competitive advantage to choose the right suppliers. If not, firms run a high risk of inefficiently utilizing their outsourcing and licensing agreements. Second, the misidentifying of potential technological problems can clearly lead to false choice of patents rights. As a result the technological integration process is mismanaged. Finally, firms might be lacking expertise in outsourcing activities. As a result firm's absorptive capacity should be properly engineered to ensure the maximum gains from technology transfer and acquisition especially if the knowledge acquired is complex and tacit. As external technology acquisition triggers organizational learning, the absence of firm's internal knowledge process development is an obstacle. As prior in-house R&D increases a firm's absorptive capacity, in turn it enhances the external technology acquisition process.

In LMT, firms are highly dependent on externalizing knowledge intensive processes. This is primarily due to two reasons. First, the daily nature of the knowledge needed is generally not intense and is often centred on process innovation. Therefore, even with the internalization of technology development, the return on that form of in housing is humble. Second, in the case where highly intense knowledge is needed, externalizing the development, through one of the externalization mechanisms if obviously more economic. As a result, firms in LMT traditionally seek knowledge from identifiable, limited sources from experts in their industries that are usually HT. For this reason, technological competitive advantage decreases, since competitors absorb the same knowledge from the same sources.

Externalization necessitates technology fusion. Technology fusion is the integration of the various sources of knowledge to produce one technology (Kodama, 1992). In his study, Freddi (2009) excludes the role of IT in the fusion process based on the fact that IT is regarded in LMT as a separate body of knowledge. Accordingly, the use of IT as an example of GPT in LMT should be ignored. This statement cannot be generalized for all segments of IT, where for instance it neglects the role of open source software that can allow changes to its core architectures and embodiment of knowledge in its core functions. Consequently, it could be argued that the role of IT, as a product of HT in LMT is evident, both to enhance process innovation and to serve as a fusion medium to the various technological sources in the LMT. This brings us to our thirst hypothesis on technology:

H3: Firm Technology: In HT, firms are generally focused on developing GPT, with high modularity. In contrast, firms in LMT are focused to produce systemic products and technologies, based on technologies offered from suppliers.

As a result, interdependence occurs between the two sectors, where LMT generates the demand and HT acts as a supplier that fulfils it. This inter-dependability is of significant impact on both sectors. For instance, if LMT decreases its demand, HT will suffer a tremendous decrease in its revenues, putting at risk its in-house R&D. And since the LMT is generally positioned as a user (Robertson & Patel 2007), and the HT as the producer, LMT could be seen as one of the main factors influencing the HT innovation diffusion process. Therefore, an increasing technological adoption by the LMT, results in higher diffusion rates for the HT innovation. The ability of the LMT sector to diffuse innovations enhances its capability of adapting the innovations to their internal use. In the same vein, this puts more pressure on HT to produce configurable, modular products to markets. This phenomena of adaptation of configurable products, added more to LMT price competition wars. It enabled the sector to compete on design, functionality and quality (Sanatamaria et al., 2009).

This shift and renewal phenomena occurring at the LMT firm level is motivated by the increasingly sophisticated tastes driven from international expansion, while maintaining high standards for safety and regulations provided by international and governmental regulators. This can be witnessed in the Food, Drink and Tobacco (FDT) industry. For instance, in studying patenting activities, Mendonca (2009) found that the Food, Drink and Tobacco (FDT), is witnessing an unprecedented growth in patenting activities. This recent growth is explained by the change in tastes due to the internationalization of the industry, where tastes became more complex, diversified and with the general directive of enhancing the standards for safety and regulations. Generally it was found that patents have a stronger impact on firms in HT than in LMT, and that the effect of the patent portfolio size is highest in HT, compared to that of the LMT. However, Lichtenthaler (2009) found that the quality of the patent portfolio is higher in the case of HT than that of LMT.

Patenting is one way of appropriating firms' R&D investments. The OECD classifies industries according to the percentage of investment in R&D with respect to turn over. According to OECD (1994), HT firms are generally investing more than 5% in R&D, while LMT less than 5% and LT invest less than 0.9% in R&D. This typically low investment in R&D explains the LMT's low intensity of R&D and the marginalized importance of knowledge appropriation through

patenting, like that found in the paper industry (Ghosal & Nair-Reichert, 2009). This in turn has affected the likelihood of the LMT sector to bring any radical innovations, and increased its propensity to further invest in process innovation, more tied to learning by doing, or learning by using (Lundvall,1988) or further including learning by interacting, learning by producing and learning by searching (Lundvall & Johnson, 1994). This is confirmed by Chen (2009) who shows that the main value creation in LMT is primarily due to craftsmanship, learning by doing, training and experimental knowledge. This is a contrast to the HT that is mainly focused on radical innovation and formal R&D activities.

When considering knowledge, apart from technologically specialized firms, customers generate ideas and solutions that are tightly integrated with the problem being faced. Their knowledge is tacit and is difficult to evaluate. In contrast to customers, R&D organizations and universities are extremely theoretical and their knowledge is usually a bit distant from the application. As a result, firms in HT are always faced with adaptation issues when using university based knowledge. Despite this adaptability requirement, it is found that collaborating with R&D institutions is more likely to exhibit a higher degree of innovativeness, a reason why HT are the main beneficiary of the explicit knowledge developed by formal ties with universities and research labs. Due to tacit nature of the knowledge circulated, LMT firms use imitation strategies with a leakage risk. In that context, suppliers are a considerable source of knowledge, providing various components of the final product (Grimpe & Sofka, 2009). Consequently, firms in LMT seek market knowledge and are more inclined to follow the open innovation model, while HT generally follows the linear model of innovation where the R&D is the main seed of innovation in that sector.

This externalized vision of knowledge acquisition broadens the scope of knowledge search (Grant, 1996), as in LMT. However, it does not allow the necessary depth of knowledge search to create unique radical technologies. This is a contrast to HT that is characterized by the necessary breadth of knowledge search to diversify its technological frontier, together with the required depth, to provide distinguished breakthrough innovations. This mix of breadth and depth search distinguishing the HT differentiates the sector with a remarkable return on R&D. Depth and breadth search strategies can be found in the work of Laursen & Salter (2006), Katila and Ahuja (2002) and Grimpe & Sofka (2009). Our fourth, and last, hypothesis of the section is thus:

H4: Firm Knowledge: In HT, the primary source of knowledge development is internal, and from collaboration with research institutes and universities. Patenting activities are the form of formal R&D output for HT. For LMT, the primary source of knowledge development is from collaborating with customers, and suppliers (Santamaria et al., 2009; Tsai and Wang, 2009). This form of collaboration in LMT encouraged learning by doing and learning by using (Lundvall, 1988).

External to the firm factors (from without)

Chesbrough's (2003) open innovation model emphasizes the role of external actors to enhance a firm's innovation performance. There are four identified interconnected factors by Chesbrough (2003) that pushes toward the direction of open innovation: increasing mobility and availability

of skilled workers, venture capital market making funds available for entrepreneurs, external options to introduce new ideas, increased capabilities of external suppliers. The first two points characterize the HT sector, whilst the following two address the LMT sector.

On the one hand, various studies focusing on industrial clusters have identified various factors that lead to such agglomerations. The increased mobility of skilled workers has certainly increased the competitive advantage of the various clusters in different continents. As initiated by Saxenian (1994) in Silicon Valley, this can be witnessed in Ottawa, Montreal, Cambridge, etc. This availability of skilled workers has been found to be attributable to the proximity of universities, competitive and complementary firms, in the firm's own cluster. The majority of those relatively new clusters were dominated by HT sectors, which often include telecommunication, biotechnology and aerospace. Furthermore, a number of studies like that of Niosi (2003) have targeted venture capital and how it motivates innovation in the various clusters, and examples are extremely wide for HT firms that depended heavily on venture capital to grow from a small size to a large enterprise.

On the other hand, this informality in knowledge transfer and production added to the dependability on external agents as users with complex demands has contributed positively to the various LMT industries such as the automobile industry (Carlsson, 1995; Chen, 2009). These interactions between LMT and complex users' demands increased the competence of LMT, through the various means of learning, and problem solving techniques addressing complex users' needs. The constant interaction between LMT firms and their clientele not only affected mastering technological 'process innovation', it also developed those firms' market intelligence, learning from their customers the latest technological and market trends. These issues raise the next four hypotheses concerning customers, suppliers, universities and competitors:

H5: Customers: HT firms are serving customers with more complex needs, while LMT firms depend on their customers to provide expertise about product's operation. Furthermore, it is expected that LMT would be relying on technologies produced by LMT. Technologies offered by HT to LMT are modular products to fit their existing environment. Therefore, technologies acquired by LMT customers are developed to fit operations of other technical systems.

H6: Suppliers: In LMT, knowledge and technologies are acquired through interaction with external entities, such as suppliers and customers. HT firms are less dependent on suppliers then their peers from LMT (Chen, 2009; Heidenreich, 2009). While HT could be seen as entrepreneurial dominated, the LMT is supplier dominated. H6 aims at confirming Pavitt (1984) taxonomy.

H7: Universities: In HT, firms depend more on collaboration with universities, than LMT. Consequently HT firms are expected to bring intensive knowledge in the academic fields.

H8: Competitors: HT firms depend less on collaborating with competition than the case of LMT.

The role of government is historical, and unique in the development of HT. This role does not have the same effect on LMT at present. One reason is that governments are mainly focused on industries that provide higher returns on investment, higher GDP and employment rates. While there is evidence of the failure of government to directly provide innovation to the industry, the

supporting role of government in Taiwan has measured a success (Chen, 2009). This brings us to our last hypothesis on the role of government:

H9: Government: Governments are more focused on the HT due to its economic benefits. Consequently, governments offer HT firms more resources and more tools to regulate and protect firms' technological edge. This focus is expected to be less for LMT.

Of course, hypotheses from "within" (H1 to H4), and from "without" (H5 to H9) are full of commonalities that are complementary in nature as will be seen in Table 1. The purpose here is to give a clear picture of the interaction between the firm and its environment. This interaction in our view is based on knowledge sharing, and technology acquisition between the various entities in the model presented in figure 1.

Data, Variables and Methodology

Data

A survey questionnaire was sent to more than 900 firms of which 736 were considered in our analysis. The questionnaire targeted five areas addressing the context of innovation of the firm in its own sector. The first regards the nature of customers and their needs. The second focuses on the nature and extent of scientific and technical knowledge production. Thirdly, the factors that influence innovation at the firm's own sector are examined. The fourth presents the resource inflows and growth in the sector. Fifth, the firm's strategic and competitive dynamics in its own sector is explored. The answers are based on a Likert scale from 1 to 7. At one end, 'one' denotes that the respondent 'totally disagree', at the other end, 'Seven' implies a 'totally agree' response. The details and description of each factor in the corresponding area is explained in the next section.

The study is thus based on firm level data. All firms are sorted according to their primary activity, and are also confirmed by their North American Industry Classification System (NAICS). The questionnaire is targeted to firms in various industries, and countries. Countries include Canada, China, USA and others accounting for 20.8%, 19.8% and 14.9% respectively of the total sample size. Table (A.1) in the appendix provides the detailed descriptive statistics of countries, number of firms, percentages and cumulative percentage. Industries include all high-tech firms such as the ICT (including telecommunication and information technology firms), pharmaceuticals and biotechnology as well as aerospace accounting for 56%, 31% and 13% respectively. All other sectors are identified as LMT in our analysis, they include manufacturing, automobile industry, pulp and paper as well as services (including banking, insurance and consulting services) accounting for 12.5%, 7.3, 7.1% and 72% respectively. For a description of the industries please consult Tables A.2 and A.3 in the appendix. In our database, the HT consists of 273 firms, and LMT of 463 firms.

Variables

This section presents the variables and how they contribute to the validation of our research hypotheses. Table 1 highlights how each entity presented previously in Figure 1, is linked to our

research questions. Of course each variable responds primarily to one or more research question, and provide us indirectly with complementary information about the rest of the questions. The resulting matrix is presented in Table 1.

Please note that in table 1, each axis, has multiple variables. Each variable primarily addresses one of the entities in the conceptual framework marked in bold with a bold '**x**'. A variable can give indications regarding other variables and other hypotheses too, and this is marked with a regular 'x'. The name of the variable is composed as follows 'a_Hb', where 'a' is the primary entity\variable, and 'b' refers to the hypothesis number.

Customers: Firms in the survey were asked about the nature of their customers and their needs. Two questions were asked regarding this issue assessing: first, to which extent customers provide a significant expertise about how the firm's products operate (Cust_Expert_H5). Second, firms were asked to identify the complexity of customers needs (Cust_Need_H5).

Government: Firms are asked on the role of regulatory approvals to commercialize their technologies (Gov_Regu_H9). Firms were later asked whether time and resources are needed to obtain regulatory approvals, and whether this process prevents the imitation process (Comp_Regu_H8). Furthermore, the question of how intellectual property protection facilitates the value captured from innovation is also considered (Comp_Val_H8). The last question addresses whether the government allocates sufficient resources for firms to perform R&D and innovation in general, or not (Gov_Res_H9).

Axis	Variables	Cust.	Gov.	Sup.	Comp.	Univ.	Know.	Tech.	Strategy	Ab. Capacity
Customers	**Cust_Expert_H5**	**x**					x		x	x
	Cust_Need_H5	**x**					x	x	x	x
Knowledge	**Univ_KnowInt_H7**					**x**	x			x
	Univ__KnowCont_H7					**x**	x		x	x
	Sup__Know_H6			**x**			x	x	x	x
	Know__Firms_H4						**x**			x
	Know_Tech_H4			x			**x**	x	x	
	Know__Depend_H4						**x**	x		
	Know_Grad_H4						**x**			x
Factors Influencing Innovation	**Gov__Regu_H9**		**x**							
	Comp_Regu_H8		x		**x**				x	
	Comp_Val_H8		x		**x**		x	x	x	x
	Tech_GPT_H3							**x**		
	Sup_Tech_H6			**x**					x	x
	Sup__Ext_H6			**x**			x	x	x	x
	Sup__Trans_H6			**x**			x		x	x
	Strat__CostScale_H1								**x**	
	Strat_ProdProc_H1						x	x	**x**	
	Strat_Cost_H1						x	x	**x**	
Resource inflows and Growth	**Gov_Res_H9**		**x**				x	x		
	Strat_Fund_H1								**x**	
	Strat_Sales_H1						x	x	**x**	x
	Strat_Niche_H1						x	x	**x**	x
Strategy and Competition	**Comp_Change_H8**				**x**		x		x	
	Comp_Prod_H8				**x**		x	x	x	
	Tech_Speed_H3						x	**x**	x	
	Strat_Trans_H1								**x**	
	Tech_Sect_H3						x	**x**		
	AbCp_H2						x		x	**x**
	Comp_Rival_H8				**x**				x	
	Comp_Advant_H8				**x**		x	x	x	
	Comp_CostSub_H8				**x**				x	

Table 1 - Linking Variables to Research Hypotheses

Supplier: Firms are questioned about whether their new technologies are built on the latest technologies of firms in the sector. Two questions address whether the firm use different technologies in their own products (Sup_Know_H6), and if the operation of the firm's product relies on other technical system operations (Sup_Tech_H6). Finally two questions will address the external environment to the firm (Sup_Ext_H6) and how it forces unpredictable transformations (Sup_Trans_H6).

Competition: Competition is explored from various angles. First, a question is asked whether interactions between the various firms in the same sector result in new technological knowledge (Know_Firms_H4). Second, a firm is asked whether the appropriation of knowledge succeeds in minimizing the imitation strategies by firms (Comp_Regu_H8), and whether seeking this kind of appropriation sustain the firm's efforts to capture value from innovation (Comp_Val_H8). Furthermore, firms were asked various direct questions with respect to their competitors. One area addresses the frequency of entry of rivals due to new innovative products (Comp_Advant_H8), and its effect on the pace of technical change in the firm's own sector (Comp_Change_H8). The rival position versus incumbent firms is further explored

(Comp_Rival_H8), and whether those dynamics erode incumbent advantages including lost cost substitutes or not (Comp_CostSub_H8).

Universities: The role of universities is explored by two direct questions, the first addresses whether the knowledge production process in the academic domain is intense and addresses directly the need of the firm in its own sector (Univ_KnowInt_H7). The second addresses the contribution of the firm and its sector to academic research via papers, data and research ideas (Univ_KnowCont_H7).

Knowledge: Knowledge is addressed in various questions in the survey. In terms of knowledge production, questions are addressed to firms on whether their knowledge is the result of accumulation inside the firms (Know_Grad_H4), or as a process of externalization by interactions with other firms (Know_Firms_H4), customers (Cust_Expert_H5 and Cust_Need_H5), or universities (Univ_KnowInt_H7 and Univ_KnowCont_H7). Knowledge appropriation is also addressed, as well as its effect on firm's strategy. Of course since knowledge touches every entity in our model, secondary information could be derived from most of the questions. For instance, asking about the utilization of cost reductions to increase the scale of operations implies that this demands a specific type of knowledge but the question does not address knowledge directly. Therefore, in table 1, knowledge (as a vertical category) is marked for most of the questions when another part of the table addresses knowledge directly (as an axis in its own right). The relation between knowledge and technology is examined by the variable Know_Tech_H4 and Know_Depend_H4 tests dependability.

Technology: Technology can be investigated as an embodiment of knowledge. Therefore the majority of questions addressing knowledge will to some extent touch technologies as well. However, technologies are addressed directly in three main areas, integration (Sup_Ext_H6), modularity (Sup_Tech_H6) (Sup_Trans_H6), and its identity as a general purpose technology (GPT) (Tech_GPT_H3) for some sectors. Consequently, whether the technologies produced by the firm are used by a wide variety of applications are of interest, notably to distinguish firms producing GPT from those that do not. Questions addressing the above are captured from 4 different questions in the axis labelled 'Factors influencing innovation'.

Strategy: Strategies shape and get shaped by the various factors included in figure 1 and the reason for these strategic directives can be sensed from the majority of factors presented in table 1. The main 3 general strategies firms would follow are: cost (Strat_CostScale_H1) (Strat_Cost_H1), differentiation (Comp_Prod_H8) or focus (Strat_Niche_H1). From an innovation perspective, product and process innovation (Strat_ProdProc_H1), linear or open model of innovation could be added in the strategic orientation of the firm.

Absorptive Capacity: The well being of absorptive capacity is examined through a question to firms addressing their knowledge about significant developments in their own sector. This indicates the firm's ability to search for knowledge (AbCp_H2).

Methodology

This paper tests for the equality of means between HT and LMT. The original sample size is 273 for HT firms, and 463 for LMT firms. To assure the consistency of results, given the inequality

of the sample size, the 463 sample is divided into two random samples of 273 (Split half 1) and 190 (Split half 2) firms. Consequently, the same tests that are conducted on the original samples are also executed on the divided LMT sample (Split half 1 and Split half 2) with respect to HT. This methodology will help identify any discrepancy resulting from the different sample sizes with respect to test's results and implications. The results are included in Table 2 across all three samples will ensure the conformity of results.

In order to use the t-test for different sample sizes, we should first analyze the data to test if the two samples follow a normal distribution. The primarily test for normality of data is the kurtosis, and skewness test. The values of kurtosis and skewness are found to be around '0' and are in the interval [-1, +1]. Therefore data is normally distributed. Consequently, Levene's test is used to test the equality of variances, between the two samples. In the Levene test, if $p \leq 0.05$ then the t-test for unequal variances and unequal sample size is used. If $p > 0.05$ then the t-test for equal variances and unequal sample size is used.

Table 2 presents the results of the t-tests for equality of the means between HT and LMT and are analysed in the next section. Results from the t-tests illustrate the significance of the results by a 2 tailed representation. Consequently, the resultant of the 2 tailed representations is divided by two to ensure the interpretation on a one tailed scale. Those are the values presented next to each factor in Table 2. In Table 2, non significant p values are labelled (NS) and are shadowed. This presents in general, which factors were consistent across the three samples, and which were not. In the 'Split Half 1' and 'Split Half 2'. NS factors are highlighted similarly. For each of the three samples (Original samples, Split half 1 and Split half 2), the first column represents the mean response for the HT sector, the second column represents the mean response for the LMT sector, the third column shows the p-value of the test for equality of the mean and the fourth column shows the significance in terms of stars, four stars being the most significant.

Results

For *Customers*, according to the analysis of means, all three tests support the fact that HT firms dominate LMT firms in the complexity of customer needs (Cust_Need_H5). This is however false when customers offering expertise to firms are examined (Cust_Expert_H5). In Split half 2, the difference is not significant for the sample of 190 firms. From that, we can primarily highlight that HT firms are serving more complex clients than that of LMT firms. However, firms in both sectors are closely aligned with their customer needs. For *knowledge,* findings demonstrate that HT is much more dependent on explicit knowledge resulting from research labs and universities, if compared with the LMT (Univ_KnowInt_H7 & Univ_KnowCont_H7). This reveals the close relationship between HT firms and universities and academic institutes, and their dominant reliance on the classical linear model of innovation. Seeking new knowledge, compared to the LMT, firms in HT benefit tremendously from interactions between the various firms in their own sectors (Know_Firms_H4). Systems integration and modularity are more intense in HT than in LMT (Sup_Ext_H6 & Sup_Trans_H6). Consequently the dependency on suppliers is high compared to LMT (Sup_Tech_H6). One striking result is the significant difference between LMT and HT when the firm is asked about is reliance on the same stable

technological base. LMT relies far more than HT on a stable technological base (Know_Depend_H4). This shows the dynamic nature of HT compared to the technologically mature LMT. Another, consistent result is that firms in both sectors produce knowledge based on gradual internal accumulation of experience (Know_Grad_H4). All results are consistent for all factors in the three comparisons. This highlights the consistency of all finding resulting from this knowledge axis.

Factors influencing innovation in the firm's own sector provide interesting results. First, it was expected that HT will advance the LMT sector when comparing the importance of regulatory approvals. Our findings suggest that LMT and HT both seek regulations (Gov_Regu_H9), and that regulations limit imitative strategies in both sectors (Comp_Regu_H8). Those results confirm recent findings that suggest that LMT firms are currently seeking regulatory approval ever more than before due to, for instance the more aggressive health regulations imposed by governments and the international communities. Those findings are consistent across the variants of the sample, suggesting certain robustness. HT, as expected, showed higher deployment of intellectual property protection (Comp_Val_H8). HT firms are more likely to capture value from innovation using IPs than their peers in LMT. In terms of modularity, integrations, interconnectivity, results of HT exceeds that of the LMT (Sup_Tech_H6, Sup_Ext_H6& Sup_Trans_H6), supporting the previous argument that suppliers in the HT are actually integrating various components into their products and hence depend on their suppliers in the process of product development.

Axis	Variables	*ORIGINAL SAMPLES* HT N=273	LMT N=463	P/2		*SPLIT HALF 1* HT N=273	LMT N=273	P/2		*SPLIT HALF 2* HT N=273	LMT N=190	P/2	
Customers	**Cust_Expert_H5**	5.22	4.94	0.0065	***	5.22	4.89	0.0065	***	5.22	5.01	0.0590	NS
	Cust_Need_H5	5.81	5.20	0.0000	****	5.81	5.13	0.0000	****	5.81	5.29	0.0000	****
Knowledge	**Univ_KnowInt_H7**	4.95	4.41	0.0000	****	4.95	4.36	0.0000	****	4.95	4.50	0.0010	****
	Univ__KnowCont_H7	4.79	4.12	0.0000	****	4.79	4.07	0.0000	****	4.79	4.20	0.0000	****
	Sup__Know_H6	5.57	4.79	0.0000	****	5.57	4.79	0.0000	****	5.57	4.78	0.0000	****
	Know__Firms_H4	4.70	4.29	0.0000	****	4.70	4.30	0.0010	****	4.70	4.28	0.0015	***
	Know_Tech_H4	4.84	4.47	0.0005	****	4.84	4.46	0.0010	****	4.84	4.48	0.0045	***
	Know__Depend_H4	4.26	4.70	0.0000	****	4.26	4.74	0.0000	****	4.26	4.64	0.0055	***
	Know_Grad_H4	5.38	5.38	0.4630	NS	5.38	5.38	0.4730	NS	5.38	5.37	0.4615	NS
Factors Influencing Innovation	**Gov__Regu_H9**	4.57	4.46	0.2355	NS	4.57	4.47	0.2870	NS	4.57	4.44	0.2440	NS
	Comp_Regu_H8	3.89	3.76	0.1695	NS	3.89	3.77	0.2170	NS	3.89	3.74	0.1980	NS
	Comp_Val_H8	4.77	4.17	0.0000	****	4.77	4.20	0.0000	****	4.77	4.11	0.0000	****
	Tech_GPT_H3	5.21	4.69	0.0000	****	5.21	4.68	0.0000	****	5.21	4.71	0.0005	****
	Sup_Tech_H6	5.66	5.16	0.0000	****	5.66	5.15	0.0000	****	5.66	5.17	0.0000	****
	Sup__Ext_H6	5.84	5.37	0.0000	****	5.84	5.43	0.0010	****	5.84	5.29	0.0000	****
	Sup__Trans_H6	5.35	4.89	0.0000	****	5.35	4.93	0.0010	****	5.35	4.83	0.0005	****
	Strat__CostScale_H1	4.99	5.03	0.3650	NS	4.99	5.16	0.0985	NS	4.99	4.85	0.1810	NS
	Strat_ProdProc_H1	4.13	4.44	0.0045	***	4.13	4.49	0.0030	***	4.13	4.36	0.0600	NS
	Strat_Cost_H1	4.79	5.13	0.0015	***	4.79	5.22	0.0005	****	4.79	5.00	0.0685	NS
Resource inflows and Growth	**Gov_Res_H9**	3.86	3.18	0.0000	****	3.86	3.19	0.0000	****	3.86	3.17	0.0000	****
	Strat_Fund_H1	3.51	3.10	0.0005	****	3.51	3.04	0.0000	****	3.51	3.18	0.0145	**
	Strat_Sales_H1	4.35	3.65	0.0000	****	4.35	3.70	0.0000	****	4.35	3.58	0.0000	****
	Strat_Niche_H1	4.72	4.10	0.0000	****	4.72	4.16	0.0000	****	4.72	4.02	0.0000	****
Strategy and Competition	**Comp_Change_H8**	4.98	3.77	0.0000	****	4.98	3.86	0.0000	****	4.98	3.65	0.0000	****
	Comp_Prod_H8	4.30	3.42	0.0000	****	4.30	3.42	0.0000	****	4.30	3.42	0.0000	****
	Tech_Speed_H3	5.06	3.78	0.0000	****	5.06	3.84	0.0000	****	5.06	3.70	0.0000	****
	Strat_Trans_H1	4.80	4.55	0.0120	**	4.80	4.70	0.2080	NS	4.80	4.32	0.0005	****
	Tech_Sect_H3	4.81	4.19	0.0000	****	4.81	4.33	0.0000	****	4.81	3.98	0.0000	****
	AbCp_H2	4.32	3.89	0.0000	****	4.32	3.96	0.0040	***	4.32	3.80	0.0000	****
	Comp_Rival_H8	5.17	4.95	0.0185	**	5.17	4.92	0.0215	**	5.17	4.99	0.0815	NS
	Comp_Advant_H8	4.55	4.49	0.3160	NS	4.55	4.46	0.2575	NS	4.55	4.53	0.4650	NS
	Comp_CostSub_H8	4.41	4.55	0.1375	NS	4.41	4.60	0.0970	NS	4.41	4.48	0.3265	NS

Note: ****, ***, **, * represent significance at the 0,1%, 1%, 5% and 10% levels respectively.

Table 2 - t-test results (original samples and LMT split samples)

Moreover, technologies produced in the HT are used for a wide variety of applications. This confirms that HT, as a breed of the third industrial revolution, is producing general purpose technologies (GPT) (Tech_GPT_H3). Those results are consistent across all samples. Two out of three samples, confirm that LMT is much more concerned with cost reductions derived by increasing the scale of operations. However, all results are not significant. This result is interesting, since it demonstrates that HT is concerned with production scale exactly like scale intensive sectors. In the same vein, all samples confirm that most of the firm's products face several cost constraints, with only one non significant sample. This suggests that LMT firms are generally more cost focused (Strat_Cost_H1). HT firms also try to minimize cost by increasing the scale of operations (Strat_CostScale_H1). All samples confirm that LMT firms are more

concerned with improving production process that finally brings higher returns that product innovation (Strat_Prod_Proc_H1). One of the three samples is however non significant.

Examining *resource inflows and growth,* results are consistent across all samples, and highlight that resource inflows and growth are more dynamic and dominant in HT than LMT. Results suggest that governments still allocate more resources to support R&D and innovation to HT (Gov_Res_H9). Dynamism in the sector, represented by entry of innovative start-ups that have easy access to funding far dominates in HT than in LMT (Strat_Fund_H1). Furthermore, sales grow significantly faster in HT than LMT (Strat_Sales_H1). This growth in sales is actually boosted by new niches, in a turbulent sector. This suggests that HT firms are following a differentiation and focus strategy (Strat_Niche_H1), compared to LMT that mainly focus on cost, and enhancing process innovation (Strat_Cost_H1).

Analyzing *strategy and competition* firms in HT are faced with a remarkable fast pace of change compared to LMT (Comp_Change_H8). In HT, rivals enter markets due to their innovative products (Comp_Prod_H8). Technological advancement accelerates at a very fast pace (Tech_Speed_H3). Results for Comp_Prod_H8 and Tech_Speed_H3 enormously differentiate HT from LMT, with the highest significant difference of means across all questions answers. In HT, external factors are forcing unpredictable transformations (Strat_Trans_H1). This result is not significant in Split Half 1. However we notice that the significance level is very small. This indicates that both LMT and HT are influenced by unpredictable transformations. The turbulence of the sector and breakthrough innovations are the major characteristics of the HT sector and the results are consistent for all samples. Competition is extremely severe in both sectors but slightly higher in HT (Comp_Rival_H8). Another important result is related to low cost substitutes (Comp_CostSub_H8); all results across all samples, are non significant for that factor. However in all samples, LMT is slightly higher than HT firms. This suggests that LMT still is focusing on cost; however HT too is facing severe cost substitution attacks. Finally the results concerning the variable AbCp_H2 suggest that HT have a better knowledge search strategy than LMT, indicating a more coherent and efficient absorptive capacity.

Discussion

This section will revisit our hypotheses and verify whether they were validated by our analysis.

From within

H1: Strategy: Results suggest that HT firms are still generally inclined towards more differentiation, while their peers in LMT are more inclined towards cost. Those results were however not of high consistent significance. On the one hand, firms in HT are seen to put considerable weight on cost reductions through increasing the scale of operations. Equivalently, the tests indicate that a good portion of LMT firms are realizing the importance of product innovation compared to process innovation, while there is a considerable reference that differentiation and product innovation dominate in HT, and that cost focus and process innovation dominate LMT. Those results are not consistent across all samples, and sometimes are not significant. Consequently, results are implying major strategic shifts and are pointing

towards a renewal process in both sectors. Firms in HT, while focusing on product and breakthrough innovation that are fundamental in differentiation strategies are also occupied with large scale operations to minimize cost. Those results are interesting, and their market proofs are numerous. Take for instance, Telecommunication Equipment Manufacturers (TEM). TEM firms are identified as HT, innovating and brining products to market through product innovation. However the same firms are producing large scale production goods such as routers, multiplexers and others. It is obvious that firms in that segment of the industry, while focusing to bring new innovations to market, are getting more cost aware then they previously were. This new strategic shift combining a mix of differentiation and cost focus is one of the major strategic directives that those firms followed after the internet bubble boom in 2001.

On the other hand, LMT firms, which are mainly focused on process innovation and cost, are bringing new innovations to market and are aiming to differentiate their products. Recent literature, like Robertson (2009) confirms the shift towards differentiation but the majority of literature would still claim that LMT firms are still focused on process innovation. Those results are apparently opposing in principle, however they are complementary. Firms in LMT while seeking differentiation from other firms could seek the enhancement of their manufacturing process, and in that case they would seek process innovation. Those firms could also try to introduce new products to market in order further differentiate them from competition, increase market share, and enhance their profitability. According to our analysis, H1 is rejected.

H2: Firm Absorptive Capacity: Results suggest that firms in the HT sector are characterized with an extremely efficient absorptive capacity mechanism, if compared to LMT. Firms in HT are expected to have a higher ability to search for unexpected market trends. On the one hand, this distinguished configuration in HT enables firms to interact with various internal and external entities to absorb and develop technical knowledge. On the other hand, LMT firms seem on the contrary to be in the process of renewal, by building internally on a stable technological base, while firms in HT are still faced by unexpected market moves. This suggests that while HT firms are better equipped internally to develop knowledge, their external market interactions do not serve them well to predict unprecedented moves. According to our analysis, H2 is rejected.

H3: Firm Technology: Results suggest that HT is a prime producer of GPT compared to LMT. Those GPTs serve a wide variety of applications, are interoperable, modular and configurable. This explains the reason why firms in HT are aligned with their complex customer needs. According to our analysis, H3 is accepted.

H4: Firm Knowledge: Our results suggest that HT firms are more active externally than LMT. In the same vein, both sectors generate new knowledge from their gradual accumulation internally. Those results again highlight a strategic shift and renewal especially on the LMT side. On the one hand, results suggest that HT firms far dominate LMT firms in the collaboration with universities and production of explicit scientific knowledge. Consequently, HT firms are still highly dependent on the linear model of innovation. This domination of the linear model did not however nullify the importance of open innovation, where it is seen that HT firms still dominate knowledge production by interaction between firms. This is probably due to the HT firms' capacity to invest in appropriating their knowledge, an act that minimizes the risks related to collaboration. On the other hand, HT and LMT firms are also dependent on internal knowledge

development from within. This is natural for HT, however apparently deviating from the results of recent literature that emphasizes the dependency of LMT on external links. We find this result logically satisfactory and in fact complement some recent finding on the performance of LMT firms. Recent literature, like Tsai and Wang (2009) demonstrates that while focused on the externalization of knowledge acquisition for LMT, however, they also emphasized the importance of internal knowledge development to build the firm's absorptive capacity. It was found that, if LMT firms increased investments in internal knowledge capabilities, their absorptive capacity enhances, and this renders the externalization of knowledge more efficient and beneficial to the firm. This finding again highlights a transformation in the LMT sector. In this sector, firms are now more inclined to produce internal knowledge. This could be due to cost reason, or to minimize externalizations risks, and increasing differentiation. According to our analysis, H4 is rejected.

From without

H5: Customers: HT firms are serving complex customers. This is a fact that is confirmed by our findings. Despite this complexity, both sectors are closely aligned with their customers. Our findings lead to a logical explanation: It is true that both sectors align almost equivalently with their customers, but for different reasons. On the one hand, firms in HT align to understand their client's needs and hence produce more innovative products. On the other hand, LMT firms are there to learn from customers and probably test their products that they are not able to test internally due to financial constraints. Hence, H5 is accepted.

H6: Suppliers: If we take as a fact that, LMT firms are the clients of the HT ones, our results show that technologies produced by the HT fit a wide variety of applications. Those products are highly configurable and adaptable to fit the various customers' demands. Consequently, we can deduce the LMT firms are supplier dominated, and H6 is accepted.

H7: Universities: HT firms are much more dependent on universities and explicit knowledge transfer than LMT. This finding suggests that HT firms follow the linear model of innovation. However, this dependability on the linear model, did not affect HT firms to equivalently consider open innovation. HT firms are seen very able to master the mix of the two strategies of innovation. Historically, HT firms are products of universities. This close relation with the academic research institutes, were not dropped facing market changes. In fact, this relation advanced, while adapting with the open innovation model to cope with the changing concepts of design, and modularity. Hence H7 is accepted.

H8: Competition: HT firms are still dominating external collaboration with firms, compared to LMT firms. This is probably due to the intellectual property protection that surrounds innovations of HT firms. Consequently the risk of external interactions is often less with HT than LMT. As a consequence, H8 is rejected.

H9: Government: In general Governments allocated much more resources to support innovation for the HT sector. Furthermore, intellectual property protection is much more often used to appropriate innovations for HT firms. Regulatory approvals are used by both sectors equivalently. This finding is interesting, and contradicts our primary hypothesis for LMT. This contradiction supports recent findings of Mendoca (2009) that suggest that LMT firms are

currently seeking to appropriate innovation and that regulatory forces play a key role in that sector. Since the war of standards and regulatory forces has dominated HT for a couple of decades, regulation is dominating the LMT sector as well. So in general, governments are supporting the HT to produce more innovation and regulating the industry. In contrast, governments are not supporting the LMT equivalently, and are controlling the regulatory forces of that sector. This is driven by the increased public awareness for health, security and safety for LMT products. Our last hypothesis H9 is thus rejected as well.

Implications for Theory and Practice

On the theoretical level, one major implication of this transformation and renewal process is the OECD sectoral classification itself. This new transformation implies an expected increase of investment in the LMT sectors that are currently witnessing support to enhance their firms' internal R&D. This phenomenon will most likely change the definition of OECD of LMT. While generally, the OECD classifies high tech firms to be investing more than 5% of their turn over on R&D, an increase in that direction might lead to a shift from some of the medium-high tech firms to the high tech zone. In the same vein, with the current economic crisis, the cost awareness regime that HT firms are increasingly deploying, together with the tightening of internal R&D investment, the classically defined high tech firms that will cease to invest in R&D will probably slip to more of a medium tech industry, according to the OECD definition. If a leader-follower process emerged, together with a consistent flow of high tech firms reducing R&D investment, the whole sector might transform, and join a lower classification. This suggests the redefinition of the OECD to the sectors undergoing the renewal and transformation processes. Otherwise, we might witness high tech firms slipping into lower categories of sectoral classification.

In practice, the various agents presented in the paper will be affected by this renewal and transformation process. Universities that probably depended more classically on high tech firms for contracts might need to diversify their collaboration agreements to include low and medium tech firms. This necessitates that firms in LMT, which increasingly depend on internal research, increase their collaboration with universities so that it can provide the same role it does with the HT industry. High tech firms that are seeking to be more cost aware, however are least likely to change their innovation mix to increase their dependency on universities than internally, due to their cost minimization process. Furthermore, Governments that have once encouraged HT, should be more aware that HT might not be able to sustain and provide the same growth levels it once provided, and hence the encouragement of the LMT might be more helpful in order to increase economic growth, and decrease unemployment rates.

Conclusion and Future Research Work

A renewal and transformation is occurring to both the LMT and HT sectors. LMT is shifting towards differentiation, while HT is shifting towards cost focused strategy. Furthermore, HT firms that are proven to be generally following the linear model of innovation are equivalently utilizing the open innovation model. And firms in LMT that are generally conceived to be supplier dependent are shifting to produce internal knowledge. This renewal process did not

misbalance the supplier, user role that HT and LMT play respectively. In fact our results show that LMT is still the user of the GPT that HT produces. Additionally, HT firms that are expected to have a more developed absorptive capacity sometimes fail to predict market transformations compared to their peers in LMT. In the same vein, LMT firms seem to be developing their internal technological arsenal that makes them capable to build on a stable technological base. Governments give more support to the HT. However, both sectors are equivalently under pressure from regulatory forces. This again reinforces our hypothesis that both sectors are going through a transformation and renewal phase.

The study at hand, has comparatively analyzed the two, HT and LMT sectors. The analysis has brought interesting results; some supporting existing literature and others that were not. The general picture confirms a transformation of both sectors. The HT sector, that often brought non traditional strategies to innovate and bring products to market, is also considering classical techniques used by the mature of industries of LMT. The LMT sector that is classically viewed as a lagging sector compared to the HT, is seeking non traditional strategies, such as more focusing on differentiation than cost, and focusing on internal innovation to increase it competitive advantage. Extending the analysis of the present findings, our future research work will include two additional dimensions to our current analysis. The first is a cross country analysis, and the second is across firms various sizes and structures. This in turn will deepen our current understanding of the transformation and renewal process that those two sectors are undergoing.

Appendix

Top 10 Countries			
Countries	**Number of Firms**	**Percentage**	**Cumulative Percentage**
Canada	153	20.8%	20.8%
China	146	19.8%	40.6%
USA	110	14.9%	55.5%
Peru	50	6.8%	62.3%
South Korea	43	5.8%	68.1%
France	31	4.2%	72.3%
Switzerland	12	1.6%	73.9%
UK	12	1.6%	75.5%
Sweden	8	1.1%	76.6%
Germany	7	1.0%	77.6%
Others	164	22.4%	100.0%
Total	736		

Table A. 1 – Main countries covered in our database

HT Sectors	Number of Firms	Percentage	Cumulative Percentage
Information and Communication Technology (ICT)	153	56.0%	56.0%
Biotechnology and Pharmaceuticals	85	31.1%	87.2%
Aerospace	35	12.8%	100.0%
Total Number of Firms	273		

Table A. 2 – High technology sectors

Top 10 LMT Sectors	Number of Firms	Percentage	Cumulative Percentage
Manufacturing	58	12.5%	12.5%
Chemical	42	9.1%	21.6%
Mining	37	8.0%	29.6%
Automobile	34	7.3%	36.9%
Services	72	15.6%	52.5%
Pulp and Paper (Including Forestry)	33	7.1%	59.6%
Building and Construction	31	6.7%	66.3%
Utilities	59	12.7%	79.0%
Transportation	26	5.6%	84.7%
Food Industry	25	5.4%	90.1%
Others	46	9.9%	100.0%
Total Number of Firms	463		

Table A. 3 – Top 10 Low and Medium Tech Sectors

References

Bruland, K., Mowery, D., 2005. Innovation through time. In Fagerberg, J., Mowery, D.C., Nelson, R. R. (Eds), *The Oxford Handbook of Innovation*. Oxford University Press, Oxford, pp. 349-379

Carlsson, B. (Ed.), 1995. *Technological systems and Economic Performance: the case of Factory automation*. Kluwer Academic Publishers, Boston

Chen, L., 2009. Learning through informal local and global linkages: The case of Taiwan's machine tool industry. *Research Policy* 38 (2009) 527-535

Chesbrough, H., 2003, *Open Innovation-The new Imperative for creating and profiting from technology*. Harvard Business School Press, Boston

Cohen,W.M., Levinthal, D.A., 1990. Absorptive capacity: a new perspective of learning and innovation. *Administrative Science Quarterly* 35, 128-152.

Fagerberg, J., 2005. Innovation: a guide to the literature. In: Fagerberg, J., Mowery, D., Nelson, R. (Eds.), *Oxford Handbook of Innovation*. Oxford University Press, Oxford, pp. 1-26.

Freddi, D., 2009. The integration of old and new technological paradigms in low- and medium-tech sectors: The case of mechatronics. *Research Policy* 38(2009) 548-558

Freeman, C., Louca, F., 2001. *As Time Goes By: From the Industrial Revolutions to the Information Revolution*, Oxford: Oxford University press

Freeman, C., Perez, C.,1988. "Structural Crises of Adjustment: Business Cycles and Investment Behavior." In G. Dosi, C. Freeman, R. Nelson, G. Silverberg, and L. Soete (eds), *Technical Change and Economic Theory*, London: Pinter, 36-66

Ghosal, V., Nair-Reichert, U., 2009. Investments in modernization, innovation and gains in productivity: Evidence from firms in the global paper industry. *Research Policy* 38(2009) 536-547

Gardner Publication, 2007. 2007 World machine tool output and consumption survey, http://www.gardnerweb.com/consump/survey.html.

Grant, R.M., 1996. Toward a knowledge-based theory of the firm. *Strategic Management Journal* 17, 109-122.

Grimpe, C., Sofka, W., 2009. Search patterns and absorptive capacity: Low- and high-technology sectors in European countries. *Research Policy* 38 (2009) 495-506

Heidenreich, M. 2009. Innovation patterns and location of European low- and medium-technology industries. *Research Policy* 38 (2009) 483-494

Helpman, E. (ed.), 1998. *General Purpose Technologies and Economic Growth*, Cambridge, Mass: MIT Press

Katila, R., Ahuja, G., 2002. Something old, something new: a longitudinal study of search behavior and new product introduction. *Academy of Management Journal* 45 (6), 1183-1194

Kodama, F., 1992. Technology fusion and the new R&D. *Harvard Business Review* 70 (4), 70-78.

Laursen, K., Salter, A., 2006. Open for innovation: the role of openness in explaining innovation performance among UK manufacturing firms. *Strategic Management Journal* 27, 131-150.

Lichtenthaler, U., 2009. The role of corporate technology strategy and patent portfolios in low-, medium- and high-technology firms. *Research Policy* 38 (2009) 559-569

Liu, R.-J., Brookfield, J., 2000. Stars, rings and tiers: organizational networks and their dynamics in Taiwan's MT industry. *Long Range Planning* 33 (3), 322-348

Lundvall, B.-A., 1988. Innovation as an interactive process: from user-producer interaction to the national system of innovation. In: Dosi, G., Freeman, C., Nelson, R.,Silverberg, G., Soete, L. (Eds.), *Technical Change and Economic Theory*. Pinter Publishers, New York, pp. 347-369.

Lundvall, B.,-A, Johnson, B., 1994. The learning economy. *Journal of Industrial Studies* 1(2), 23-41.

Mendonca, S., 2009. Brave old world: Accounting for 'high-tech' knowledge in 'low-tech' industries. *Research Policy* 38 (2009) 470-482

Niosi, J., 2003. Alliances are not enough explaining rapid growth in biotechnology firms. *Research policy* 32 (2003) 737-750

OECD, 1994. *Science and Technology Policy: Review and Outlook*. OECD, Paris.

OECD, 2003. *Science, Technology and Industry Scoreboard 2003 – Towards a Knowledge-based economy*. OECD, Paris.

Pavitt, K., 1984. Sectoral patterns of technical change: towards a taxonomy and a theory. *Research Policy* 13, 343-373

Robertson, P.L., Pol, E., Carroll, P., 2003. Receptive capacity of established industries as a limiting factor in the economy's rate of innovation. *Industry and Innovation* 10 (4), 457-474.

Robertson, P.L., Patel, P.R., 2007. New wine in old bottles: technological diffusion in developed economies. *Research Policy* 36 (5), 708-721.

Santamaria, L., Nieto, M., Barge-Gil, A., 2009. Beyond formal R&D: Taking advantage of other sources of innovation in low- and medium-technology industries. *Research Policy* 38 (2009) 507-517

Saxenian, A. 1994. *Regional advantage: Culture and Competition in Silicon Valley and Route 128*. Harvard University Press .Cambridge. MA.

Tsai, K., Wang, J., 2009. External technology sourcing and innovation performance in LMT sectors: An analysis based on the Taiwanese Technological Innovation Survey. *Research Policy* 38 (2009) 518-525

Viardot, E., 2004. *Successful marketing strategy for High-Tech firms*, 3rd Ed. Artech House, Inc.

Von Tunzelmann, N., Acha, V., 2005. Innovation in "low-tech" industries. In Fagerberg, J., Mowery, D.C., Nelson, R. R. (Eds), *The Oxford Handbook of Innovation*. Oxford University Press, Oxford, pp. 408-432

Zahra, S.A., Keil, T., Maula, M., 2005. New ventures' inward licensing: examining the moderating role of firm's competitive environment. *Journal of Business Venturing* 11, 189-219.